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Ordovician Bryozoa from the Llandeilo Limestone, Clog-y-fran, near Whitland, South Wales

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SYNOPSIS. A diverse bryozoan fauna is described from the Llandeilo Limestone (from the upper part of the classical Llandeilo Series), Clog-y-fran, between Whitland and St. Clears, Carmarthenshire, Wales. The fauna is dominated by trepostomes (17 species) but one cryptostome and two fenestrate species are present. Two new trepostome species, *Dittopora sanclerensis* and *Batostoma clogyfranensis*, are described.

INTRODUCTION

Ordovician bryozoans from Britain have been neglected. This neglect can be attributed to poor preservation, the need to prepare oriented thin sections for identification, and also to the lack of a strong tradition of bryozoan research in Britain. Bryozoans are commonly preserved in Ordovician rocks as decalcified moulds which are easy to recognise but are very difficult to identify to genus and species level. Calcified specimens are often only noticed when a rock is cut and thin sections or peels are prepared.

The bryozoan fauna from Clog-y-fran is particularly important because it is the most diverse of those described from the Ordovician of the British Isles. In the only previous study of a Welsh mid-Ordovician bryozoan fauna, Spjeldnaes (1963) described upper Llanvirn/lower Llandeilo silicified material from south Wales. This included abundant bryozoans: six trepostome species, two bifoliate cryptostomes and arthrostylid fragments. Due to the silicified preservation identification is particularly difficult and only two species were named: *Orbignyella favulosa*? (Phillips) and *Mesotrypa* aff. *lens* (M'Coy).

MATERIAL

The Llandeilo limestone crops out in Carmarthenshire, near Clog-y-fran Farm (SN 239161) (Strahan *et al.* 1909) between Whitland and St. Clears and to the south of Pont-y-fenni (Fig. 1). Collection *in situ* is no longer possible but blocks from a previously dug trench are available for study. The fauna is very rich; bryozoans dominate but there are also brachiopods, trilobites, echinoderms, molluscs and conularids. All material described in this study is from the *Marrolithus favus* Biozone, upper 'Llandeilo Series' (lower Caradoc Series, upper Ordovician, see Fortey *et al.*, 1995: 16), Llandeilo Limestone, Clog-y-fran.

The bryozoan fauna is extremely diverse; 20 species are described. Trepostomes dominate with seventeen species but one cryptostome and two fenestrate species are also present. Four of the 20 species from Clog-y-fran have been recognised as known species and two new species are also present. The other 14 could not be identified precisely to species level due to poor preservation or lack of material. These species are left in open nomenclature and are referred to as 'cf.', 'aff.' and 'sp.' based on the recommendations of Bengtson (1988).

All the bryozoans from this locality are abraded and incomplete. Fragments are observed in acetate peels which may be from species not described in this study but they are too small to attempt any kind of identification.

The dominant morphological form of the fauna is erect. All but two of the 17 trepostome species are erect and some are branching, but others are impossible to tell because only incomplete colonies are present. The other two trepostomes have a massive hemispherical form. This may not be a true reflection of the living bryozoan community, but the result of taphonomic processes.

BIOGEOGRAPHICAL COMPARISONS

A total of 15 genera are recognised from Clog-y-fran. All are cosmopolitan and have been previously described from outside south Wales. Ordovician bryozoans from Wales are known to have broad geographical ranges (Buttler 1991a). A long-lived planktotrophic larval stage may explain this wide dispersal (Taylor & Cope, 1987). Living cyclostomes have non-planktotrophic larvae but Taylor & Cope considered that early stenolaemates may have inherited planktotrophic larvae from their inferred ctenostome ancestors.

During the Ordovician south Wales formed part of Avalonia, along with the Ardennes of Belgium and northern France, England, southeast Ireland, the Avalon Peninsula of eastern Newfoundland, parts of Nova Scotia, southern New Brunswick and coastal areas of New England (Scotese & McKerrow, 1990). Avalonia was separated from Laurentia (North America) by the Iapetus Ocean and from the Baltica by Tournquist's Sea, both of which began to narrow in the early Ordovician. By the late Caradoc Avalonian faunas were similar to those of Baltica (Scotese & McKerrow, 1990).

As 16 of the 20 species from Clog-y-fran cannot be precisely related to known taxa it is difficult to make biogeographical comparisons, although Welsh bryozoans generally show the greatest affinity to Baltica. The four species that have been previously described are known from Baltica, North America and Wales. *Hemiphragma pygmaeum* is known from Sweden, *Graptodictya bonnemai* from Estonia and Russia, *Hallopora peculiaris* from Latvia and south Wales, and *Eridotrypa simulatrix* from Russia and North America

Species	ZOW	EXW	MXZD	MNZD	MXMD	ZWT	ZMM	DEX	DEN	DMEX	DMEN	CMM	AD	AZ	AMM
Dittopora sanclerensis	5.8 (9) 4-10	1.1 (9) 0.57-1.62	0.26 (7) 0.17-0.32	0.22 (7) 0.13-0.29	0.11 (6) 0.04-0.21	0.075 (8) 0.02-0.13	8.25 (7) 6-8	0.13 (9) 0.06-0.29	–	0.083 (9) 0.04 0.17	–	–	0.041 (7) 0.023-0.054	4.1 (3) 1-7	18 (2) 14-23
Hemiphragma pygmaeum	4.5 (2) 4-5	1.24 (2) 1.14-1.33	0.23 (2) 0.17-0.29	0.19 (2) 0.15-0.25	0.1 (2) 0.06-0.13	0.07 (2) 0.02-0.1	12.7 (2) 10-15	0.15 (2) 0.08-0.23	0.17 (1) 0.11-0.27	0.08 (2) 0.04-0.11	–	–	0.051 (2) 0.045-0.077	4.67 (2) 4-5	23 (1) 23
Hemiphragma sp.	2.5 (1) 2.5	–	0.47 (1) 0.38-0.57	0.39 (1) 0.32-0.46	–	0.02 (1) 0.02	4.3 (1) 4-5	0.36 (1) 0.29-0.49	0.62 (1) 0.16-0.87	–	–	–	–	–	–
Heterotrypa sp.	4 (1) 4	0.57 (1) 0.57	0.19 (1) 0.13-0.23	–	0.12 0.1-0.15	0.055 (1) 0.04-0.08	9 (1) 9	–	–	0.09 (1) 0.06-0.11	0.14 0.11-0.19	–	0.052 (1) 0.045-0.059	–	–
Leioclema sp. A	8 (2) 8	1.9 (2) 1.8-2	0.26 (2) 0.21-0.34	0.18 (2) 0.13-0.23	0.093 (2) 0.06-0.11	0.13 (2) 0.1-0.17	8.1 (2) 6-9	–	–	0.1 (2) 0.06-0.17	0.15 (2) 0.11-0.19	–	0.03 (2) 0.02-0.04	5.1 (2) 4-6	29 (2) 25-34
Leioclema sp. B	1.5 (1) 1.5	0.67 (1) 0.67	0.11 0.08-0.13	0.093 (1) 0.08-0.11	0.04 (1) 0.02-0.06	0.08 (1) 0.04-0.1	47 (1) 39-55	–	–	0.04 (1) 0.02-0.06	–	–	0.027 (1) 0.023-0.32	1.2 (1) 1-2	29.5 (1) 26-33
Leioclema ? sp.	12 (1) 12	2.28 (1) 2.28	0.45 (3) 0.32-0.55	0.37 (3) 0.3-0.49	0.14 (3) 0.04-0.1	0.06 (3) 0.04-0.1	3.67 (3) 2-5	–	–	0.11 (3) 0.06-0.15	0.13 (2) 0.08-0.21	–	0.09 (3) 0.05-0.12	7.7 (3) 5-9	12.5 (3) 10-17
Hallopora peculiaris	5.6 (1) 5.6	–	0.29 (5) 0.26-0.3	–	–	0.1 (4) 0.09-0.1	–	0.17 (6) 0.07-0.19	–	0.07 (7) 0.05-0.08	0.1 (7) 0.08-0.11	–	–	–	–
Hallopora aff. *wesenburgiana*	11 (3) 10-12	1.81 (3) 1.81	0.27 (2) 0.23-0.34	0.21 (2) 0.17-0.27	0.1 (2) 0.04-0.13	0.03 (2) 0.02-0.04	10.2 (2) 9-12	0.11 (3) 0.06-0.21	0.26 (2) 0.1-0.57	0.07 (3) 0.04-0.11	0.08 (2) 0.06-0.13	–	–	–	–
Batostoma clogyfranense	3.9 (23) 2-5	0.8 (22) 0.48-1.43	0.18 (23) 0.1-0.34	0.15 (23) 0.11-0.23	0.09 (21) 0.04-0.17	0.08 (21) 0.02-0.13	13.6 (19) 10-20	0.15 (22) 0.02-0.46	0.28 (23) 0.1-0.67	0.07 (23) 0.04-0.13	–	–	0.03 (21) 0.014-0.06	12.6 (12) 10-16	67.3 (5) 50-77
Batostoma cf. *polare*	4.5 (1) 4.5	1.14 (1) 1.14	0.2 (1) 0.13-0.29	0.16 (1) 0.11-0.23	0.1 (1) 0.08-0.13	0.11 (1) 0.1-0.13	10.7 (1) 10-12	0.06 (1) 0.02-0.11	0.38 (1) 0.13-0.78	0.05 (1) 0.02-0.1	–	–	0.018 (1) 0.014-0.06	14 (1) 10-16	30 (1) 30
Eridotrypa simulatrix	3.3 (4) 3-4	0.64 (4) 0.38-0.95	0.18 (4) 0.13-0.3	0.13 (4) 0.1-0.19	0.09 (4) 0.04-0.11	0.06 (4) 0.04-0.1	15 (4) 12-19	0.13 (4) 0.06-0.29	0.35 (4) 0.19-0.99	0.07 (2) 0.04-0.1	–	–	0.02 (4) 0.014-0.032	–	–
Monticulipora aff. *compacta*	4 (1) 4	1.05 (1) 1.05	0.16 (1) 0.13-0.21	0.13 (1) 0.1-0.17	0.08 (1) 0.06-0.13	0.05 (1) 0.02-0.06	28 (1) 25-30	0.07 (1) 0.04-0.13	0.15 (1) 0.08-0.23	0.06 (1) 0.04-0.08	–	0.24 (1) 0.15-0.38	0.028 (1) 0.023-0.032	4.3 (1) 4-5	47 (1) 47
Homotrypa cf. *similis*	8 (1) 8	1.62 (1) 1.62	0.23 (1) 0.17-0.29	–	0.08 (1) 0.06-0.1	0.04 (1) 0.02-0.04	–	0.1 (1) 0.08-0.15	0.26 (1) 0.15-0.4	0.04 (1) 0.02-0.08	–	10 (1) 8-12	–	–	–
Monotrypa sp.	13.5 (2) 12-15	–	0.32 (2) 0.25-0.4	0.29 (2) 0.21-0.4	–	0.02 (2) 0.02-0.04	9.2 (2) 6-15	–	1.8 (2) 0.57-2.9	–	–	–	–	–	–
Amplexopora sp.	8 (2) 7-9	1.9 (2) 1.7-2.1	0.3 (2) 0.21-0.38	0.24 (2) 0.15-0.32	0.12 (2) 0.04-0.15	0.08 (2) 0.04-0.11	11 (2) 9-13	0.09 (2) 0.04-0.19	0.23 (2) 0.1-0.38	0.05 (2) 0.02-0.1	–	–	0.05 (2) 0.03-0.07	3.9 (2) 2-5	14 (2) 12-17
Halloporina cf. *crenulata*	4.5 (1) 4.5	0.76 (1) 0.76	0.22 (1) 0.21-0.23	0.18 (7) 0.15-0.21	0.08 (1) 0.04-0.11	0.05 (1) 0.04-0.08	14 (1) 12-15	–	–	–	–	–	–	–	–

Table 1 Summary of the biometric details of all trepostome species from the Llandeilo Limestone, Clog-y-fran. In each case, upper figures are mean values, followed by the number of specimens in brackets. Lower figures are ranges. All measurements are in millimetres except for ZMM, CMM, AZ and AMM. ZOW = zoarial diameter, EXW = exozonal width, MXZD = maximum autozooecial diameter, MNZD = minimum autozooecial diameter, MXMD = maximum mesozooecial diameter, ZWT = autozooecial wall thickness, ZMM = autozooecia per mm, DEX = distance between exozonal autozooecial diaphragms, DEN = distance between endozonal autozooecial diaphragms, DMEX = distance between exozonal mesozooecial diaphragms, DMEN = distance between endozonal mesozooecial diaphragms, CMM = number of cystiphragms per mm, AD = acanthostyle diameter, AZ = number of acanthostyles per autozooecium, AMM = acanthostyles per square mm.

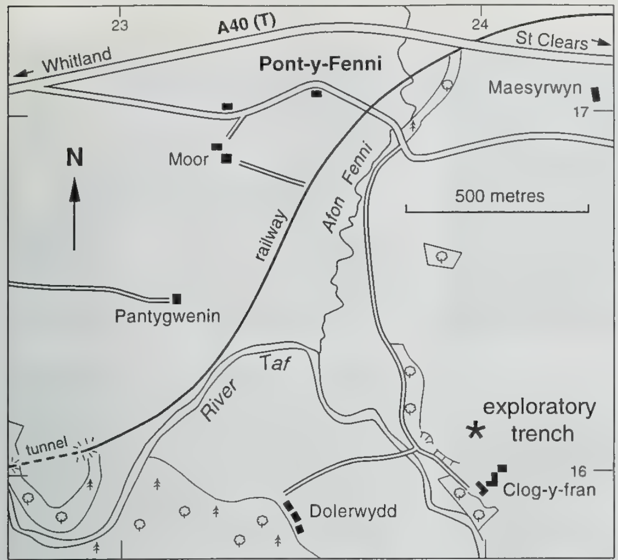


Fig. 1 Locality map showing position of exploratory trench where the limestone blocks containing the fauna were collected.

SYSTEMATIC PALAEONTOLOGY

The terminology in all descriptions is that of Boardman *et al.* (1983). All genera are placed in families based on the following sources: Trepostomata –Astrova (1978); Cystoporata – Utgaard (*in* Boardman *et al.*, 1983). Family level classification is generally unsatisfactory in Palaeozoic trepostomes and is currently being revised for the *Treatise on Invertebrate Paleontology* by R.S. Boardman.

Biometric details for all trepostome species are tabulated (Table 1). Each measurement was made up to seven times per specimen, and the means and ranges calculated for each parameter. Raw data can be found in an unpublished Ph.D. thesis (Buttler 1988). All specimens are represented by thin sections or acetate peels. Measurements given in the systematic descriptions are all mean values unless otherwise stated. All material is deposited in The Natural History Museum, London.

Phylum **BRYOZOA** Ehrenberg, 1831
Class **STENOLOAEMATA** Borg, 1926
Order **TREPOSTOMATA** Ulrich, 1882
Suborder **HALLOPOROIDEA** Astrova, 1965
Family **HETEROTRYPIDAE** Ulrich, 1890
Genus ***DITTOPORA*** Dybowski, 1877

Dittopora sanclerensis sp. nov. Figs 2–3

HOLOTYPE. NHM PD 8338.

PARATYPES. NHM PD 8333–8337, 8339–8341.

NAME. The species is named after St. Clears (Sancler in Welsh), the nearest town to the type locality.

DIAGNOSIS. Colony large, ramose. Autozooecia, with very thin, slightly wavy walls in endozone, which curve out from branch axis to intersect zoarial surface; polygonal in zoarial transverse section, rounded-circular in shallow zoarial tangential sections. Circular mesozooecia present, originating in outer endozone/inner exozone. Partial and complete diaphragms in exozonal autozooecia; numerous diaphragms in mesozooecia. Acanthostyles large and abundant in exozone.

DESCRIPTION. Zoaria erect with thick cylindrical branches, on average 5.8 mm in diameter.

Autozooecia curve out gently from the branch axis in the endozone to meet the zoarial surface at 90°. Autozooecia within the endozone have very thin, slightly wavy walls.

The exozone has an average diameter of 1.1 mm (although the range is large: 0.57–1.62 mm) and is recognised by a thickening of the zooecial walls. Autozooecia all originate in the endozone where they are polygonal in transverse section, becoming rounded-circular in the exozone, as seen in tangential sections of branches. Autozooecial in the exozone contain abundant partial diaphragms and complete diaphragms (spaced on average 0.13 mm apart) which increase in thickness distally along the autozooecia. All diaphragms are basal and are deflected orally at their junctions with zooecial walls. Their laminae are continuous with the autozooecial linings.

Mesozooecia are common and originate in the outer parts of the endozone and inner parts of the exozone. They are circular in shallow tangential sections and contain numerous thick, orally deflected basal diaphragms, spaced on average 0.83 mm apart and generally increasing in thickness distally along the mesozooecia.

Acanthostyles are abundant and large, with an average diameter of 0.04 mm and density of four per mm^2. They originate deep within the exozone and can on rare occasions indent the zooecial apertures. A hyaline core is surrounded by steeply dipping conical laminae.

Autozooecial wall thickness averages 0.08 mm in the exozone. Wall microstructure is composed of steeply inclined, U-shaped laminae. Zooecial boundaries are indistinct due to the presence of large acanthostyles which disrupt the wall structure. Frequently the autozooecia, and virtually all of the mesozooecia, are infilled with laminar calcite close to the zoarial surface. In longitudinal section this infilling consists of broad U-shaped laminae. Often large areas of adjacent zooecia are infilled.

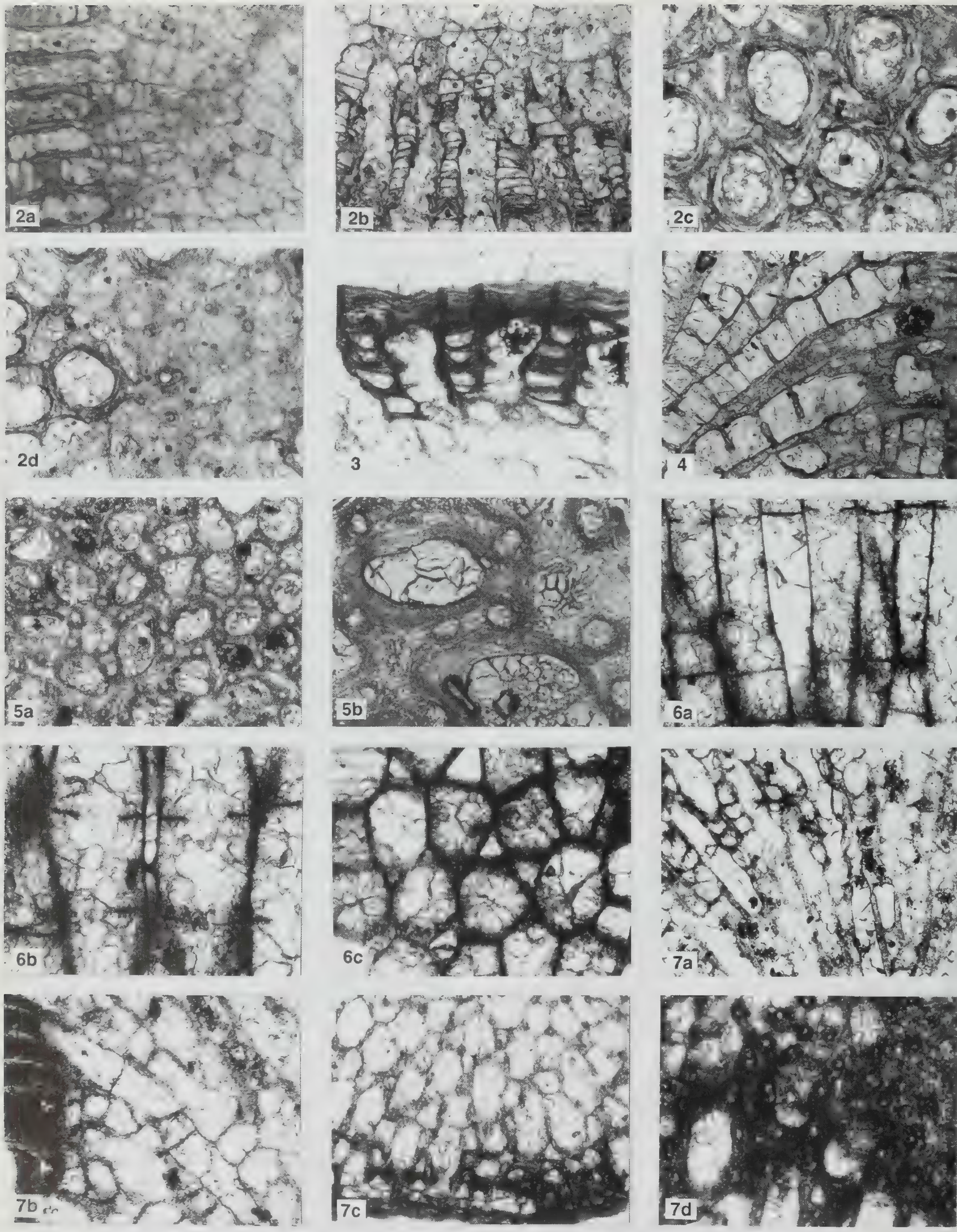
An intrazoarial overgrowth is recognised in one specimen (PD 8334). It is continuous with the exozone and has endozonal and exozonal components.

REMARKS. *Dittopora sanclerensis* sp. nov. is characterised by extremely thin endozonal walls which thicken markedly in the exozone. Partial and complete diaphragms are present in the exozonal autozooecia. Circular mesozooecia with numerous diaphragms are present. Acanthostyles are large and abundant in the exozone.

Dittopora annulata (Eichwald, 1860), from the Orthoceras Limestone (Llanvirn) in Estonia and the Glauconite Limestone in Russia, is similar internally to *Dittopora sanclerensis*. However, *D. annulata* has alternating bands of autozooecia and mesozooecia, whereas in *D. sanclerensis* they are not arranged in bands.

Modzalevskaya (1953) described two new species of *Dittopora*, *D. sokolon* and *D. ramosa*, from the western Russian Platform: *D. sokolon* has similar autozooecia, diaphragms and acanthostyles to *D. sanclerensis* but thicker endozonal walls; *D. ramosa* has similar diaphragms but smaller and more abundant acanthostyles.

A common feature of *D. sanclerensis* is that zooecia close to the zoarial surface are filled with U-shaped laminar calcite (Fig. 2). This may be because the studied material consists mainly of the basal parts of colonies with ontogenetically older zooids.


2a
2b
2c
2d
3
4
5a
5b
6a
6b
6c
7a
7b
7c
7d

Genus ***HEMIPHRAGMA*** Ulrich 1893

Hemiphragma pygmaeum Bassler, 1911 Figs 4–5

1911 *Hemiphragma pygmaeum* Bassler: 289, fig. 176.
non 1970 *Hemiphragma pygmaeum* Bassler; Nekhorosheva: 84; pl. vii, figs 5–6.

SYNTYPES. NHM D 22829, D 22536; Chasmops Limestone (upper Caradoc), Oland, Sweden.

MATERIAL. NHM PD 8331a, b.

DESCRIPTION. Zoaria erect with quite thick cylindrical branches, on average 4.5 mm in diameter.

Autozooecia curve out gradually from the branch axis to meet the zoarial surface at 90°. The autozooecia within the endozone have thick straight walls.

The exozone has an average diameter of 1.24 mm. It is recognised by a thickening of the zooecial walls. Autozooecia all originate in the endozone, where they are rounded and occasionally petaloid in transverse section, becoming rounded to circular as seen in tangential sections of branches. Autozooecial diameters average 0.19 mm by 0.23 mm within the exozone. Diaphragms are found throughout the colony but are not common. Partial diaphragms are, however, very abundant everywhere. They are spaced on average 0.17 mm apart in the endozone and 0.15 mm apart in the exozone, and tend to occur on alternating sides of the autozooecia. The direction of deflection of the laminae of the diaphragms at their junctions with zooecial walls cannot be distinguished.

Mesozooecia are present, although not common, and originate in the outer parts of the endozone. They are rounded in tangential section and have an average maximum diameter of 0.1 mm. Mesozooecia contain orally deflected basal diaphragms, spaced on average 0.08 mm apart.

Acanthostyles are large and abundant with an average diameter of 0.05 mm and density of 23 per mm^2. They originate throughout the colony and can indent the autozooecial apertures to produce a petaloid shape. In the outer exozone they are normally found in the centre of the thick walls. A large hyaline core is surrounded by steeply dipping conical laminae.

Autozooecial wall thickness averages 0.07 mm in the exozone. Wall microstructure is composed of steeply inclined, U-shaped laminae. Adjacent zooecial wall boundaries are occupied by wide granular areas. The wall structure is hard to distinguish because it is greatly disrupted by the large acanthostyles. Frequently zooecia are infilled with laminar calcite close to the zoarial surface. In longitudinal section this infilling consists of broad U-shaped laminae.

REMARKS. *Hemiphragma pygmaeum* was originally described by Bassler (1911) from the Chasmops Limestone (upper Caradoc) of Oland, Sweden but has not hitherto been recognised elsewhere. Bassler characterised the species by its 'mushroom'-shaped colonies, thick zooecial walls, large acanthostyles throughout the colony and the abundant partial diaphragms.

The specimens from Clog-y-fran are known only in section. They differ from the Swedish *H. pygmaeum* in having a straight-sided, more erect colony form and slightly smaller acanthostyles. Also the mesozooecia do not appear to originate as deeply in the colony. At present the Welsh material is placed within *H. pygmaeum* and the differences with the Swedish material are considered to represent intraspecific variability until more material can be examined.

The genus *Hemiphragma* has not be previously described from Great Britain. A second species from Clog-y-fran, *Hemiphragma* sp., is also described here. The two species are very different, *H. pygaeum* being ramose in form, with thick walls and large acanthostyles, and *Hemiphragma* sp. being hemispherical, with thin walls and ring-diaphragms.

H. pygmaeum was described from the middle Ordovician of Pai-Khoi and Vaigach Island, Russia (Nekhorosheva 1970). The illustrations, however, show thin-walled specimens with abundant diaphragms and small acanthostyles; these are considered not to be *H. pygmaeum*.

Hemiphragma sp. Fig. 6

MATERIAL. NHM PD 8327.

DESCRIPTION. Zoaria large and hemispherical, on average 2.5 mm in diameter. Autozooecia all originate from the basal lamina and curve outwards towards the zoarial surface. Autozooecial walls are straight throughout the colony; there is no differentiation between endozone and exozone. Autozooecia are large with an average diameter of 0.39 mm × 0.47 mm and are polygonal/rounded to rounded in transverse section throughout the colony. Thin diaphragms and ring diaphragms are present in all zooecia, spaced 0.62 mm apart in the endozone and 0.36 mm in the exozone. These are basal diaphragms which are orally-deflected at their junctions with the zooecial walls and have laminae continuous with the autozooecial linings.

Possible acanthostyles occur in the outer parts of the colony, but are rare. Autozooecial wall thickness averages 0.02 mm at the periphery of the colony. It is not possible to identify the microstructure from available peels and thin sections.

REMARKS. The specimen described herein is characterised by a hemispherical colony shape. Autozooecia have straight, thin walls throughout the zoarium, and the autozooecial apertures are polygonal-rounded to rounded in transverse section. Diaphragms and ring diaphragms are present in all autozooecia.

Bassler (1911: 282, fig. 170) described and illustrated specimens of *H. tenuimurale* Ulrich, 1893 from the type locality, the *Clitambonites* and *Nematopora* Beds, Lower Trenton, Minnesota and Iowa; and from the Wassalem Beds (Caradoc), Uxnorm, Estonia. The Welsh specimen is similar to the Estonian material: it has thin walls and mesozooecia are lacking, but differs in having a hemispherical rather than ramose colony, diaphragms within the endozone, and by the presence of ring diaphragms rather than partial diaphragms. *H. tenuimurale* described by Ulrich (1893) from Minnesota (see Bassler, 1911: fig. 171) has fewer diaphragms in the endozone compared to the Estonian material. Brown (1965) described specimens of *H. tenuimurale* from the Logana and Jessamine

Figs 2–3 *Dittopora sanclerensis* sp. nov. **2**, NHM PD 8338 (holotype); **2a**, longitudinal section, x22; **2b**, transverse section, x22; **2c**, tangential section, x53; **2d**, tangential section, showing infilled zooecia, x53. **3**, NHM PD 8333 (paratype); longitudinal section, showing infilled autozooecia, x37.

Figs 4–5 *Hemiphragma pygmaeum* Bassler, 1911. **4**, NHM PD 8331a; longitudinal section, showing partial diaphragms, x35. **5**, NHM PD 8331b; **5a**, tangential section, x35; **5b**, tangential section, x94.

Fig. 6 *Hemiphragma* sp., NHM PD 8327; **6a**, longitudinal section, x23; **6b**, longitudinal section, showing ring diaphragms, x37; **6c**, tangential section, x30.

Fig. 7 *Heterotrypa* sp., NHM PD 8314; **7a**, longitudinal section, x26; **7b**, longitudinal section, x47; **7c**, transverse section, showing infilled zooecia in the exozone, x37; **7d**, tangential section, x70.

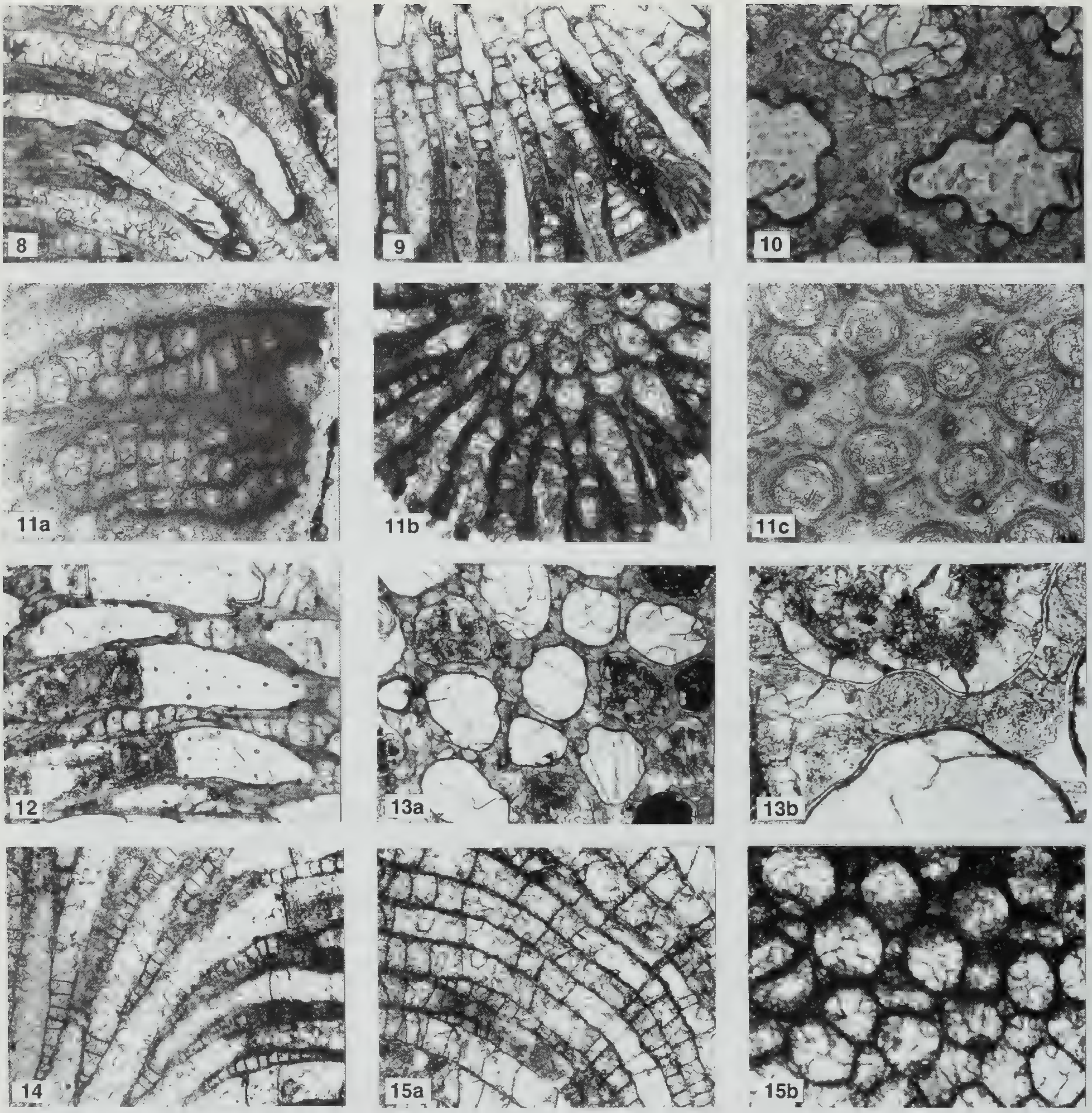


Fig. 8 *Leioclema* sp. A. NHM PD 8307; longitudinal section, x22.

Figs 9–10 *Leioclema* sp. A. **9**, NHM PD 8308; transverse section, x22. **10,** NHM PD 8307; tangential section, showing petaloid autozooecia, x101.

Fig. 11 *Leioclema* sp. B., NHM PD 8306; **11a**, longitudinal section, x86; **11b**, transverse section, x55; **11c**, tangential section, x86.

Figs 12, 13 *Leioclema*? sp. **12,** NHM PD 8138; longitudinal section, x22. **13**, NHM PD 8137; **13a**, tangential section, x30; **13b**, tangential section, showing large acanthostyles indenting autozooecial walls, x112.

Fig. 14 *Hallopora peculiaris* Pushkin (*in* Ropot & Pushkin, 1987). NHM PD 8396; longitudinal section, x22.

Fig. 15 *Hallopora* aff. *wesenberginia* (Dybowski, 1877), NHM PD 8312; **15a**, longitudinal section, x22; **15b**, tangential section, x37.

Limestones (middle Ordovician) of Kentucky which are very similar to those from Minnesota and Iowa. Restudy is needed to assess the variability within the species, and it is possible that the Estonian and American forms are different species.

Until further material can be examined, this one incomplete specimen is left in open nomenclature.

Genus *HETEROTRYPA* Nicholson, 1879

Heterotrypa **sp.** Fig. 7

MATERIAL. NHM PD 8314.

DESCRIPTION. Zoarium erect with thin cylindrical branches, on average 4 mm in diameter.

Autozooecia curve outwards gradually from the branch axis to meet the zoarial surface at 90°. Autozooecia within the endozone have thin, slightly wavy walls.

The exozone is narrow with an average width of 0.57 mm. It is recognised by a thickening of the zooecial walls. Autozooecia all originate in the endozone where they are rounded-polygonal in transverse section, becoming rounded to slightly petaloid in the exozone as seen in tangential sections of branches. Autozooecial diameters average 0.19 mm in the exozone. Diaphragms are rare in the autozooecia, and when present only one or two are found in the outer endozone and exozone. These basal diaphragms are all orally-deflected at their junctions with the zooecial walls.

Mesozooecia are common and originate throughout the endozone; their shape in shallow tangential section has not been observed. Orally deflected basal diaphragms are found along the entire length of the mesozooecia. Vertical walls are extensively constricted at the positions of the diaphragms, producing a pronounced beaded (in some cases vesicular) appearance.

Acanthostyles are large and abundant, with an average diameter of 0.05 mm. They originate throughout the colony and commonly indent the autozooecia. Acanthostyle microstructure is difficult to distinguish, but seems to consist of a hyaline core surrounded by steeply dipping conical laminae.

Autozooecial wall thickness averages 0.06 mm. Wall microstructure is composed of inclined laminae, but is hard to distinguish because the walls are greatly disrupted by acanthostyles. Frequently, the zooecia are infilled with laminar calcite close to the zoarial surface. The zooecia in large parts of the colony have been found to be all infilled. In shallow tangential sections of these areas, all that is seen is the laminar calcite wall pierced by acanthostyles.

REMARKS. Only one poorly preserved specimen of this species has been found. It is characterised by the ramose colony form and meandering endozonal walls. Autozooecia are rounded to slightly petaloid in shallow tangential sections, and beaded mesozooecia are common throughout the colony. Diaphragms are rare in autozooecia but abundant in mesozooecia throughout the colony. The irregularly shaped, beaded zooecia make this a particularly characteristic species and distinguish it from *H. sladei* described by Buttler (1991b). Identification is, however, left in open nomenclature until better preserved material can be examined.

Heterotrypa sp. is similar to the Russian species *H. ovata* Astrova, 1957, but has more weakly beaded zooecia and less prominent acanthostyles.

Genus *LEIOCLEMA* Ulrich, 1882

Leioclema sp. A — Figs 8–10

MATERIAL. NHM PD 8307–8308.

DESCRIPTION. Zoaria erect with cylindrical branches on average 8 mm in diameter.

Autozooecia curve outwards gradually from the branch axis to meet the zoarial surface at 80°–90° and have moderately thick, slightly wavy walls within the endozone.

The exozone is quite large with an average diameter of 1.9 mm. It is recognised by an extensive thickening of the zooecial walls. Autozooecia all originate in the endozone, where they are rounded-petaloid in transverse section becoming extensively petaloid in the exozone as seen in tangential sections of branches. Autozooecial diameter averages 0.18 mm by 0.26 mm within the exozone. Diaphragms are rare and frequently wholly absent in autozooecia.

Mesozooecia are very common and originate in the outer parts of the endozone and inner parts of the exozone. They are rounded and have a maximum diameter averaging 0.09 mm. The mesozooecia contain abundant orally-deflected basal diaphragms, spaced on average 0.15 mm apart in the endozone and 0.1 mm apart in the exozone, with successive diaphragms often increasing in thickness distally along the mesozooecia.

Acanthostyles are large and very abundant with an average diameter of 0.03 mm and density of 29.5 per mm^2. They originate throughout the colony and are very abundant in the exozone, where they indent the autozooecial apertures, producing a petaloid shape. Acanthostyles are larger in size in the outer exozone than in the rest of the colony. In longitudinal section acanthostyles can be identified protruding into the zooecial chambers. Acanthostyles are composed of a broad hyaline core surrounded by steeply dipping conical laminae.

Autozooecial wall thickness averages 0.13 mm in the exozone. Wall microstructure is composed of steeply inclined, U-shaped laminae. In tangential sections a thick granular layer can be identified between adjacent zooecia. Virtually all mesozooecia, and some autozooecia, are infilled with laminar calcite close to the zoarial surface. In longitudinal section this infilling consists of broad U-shaped laminae. The infilling of the mesozooecia commences in the middle exozone, whereas the autozooecia are infilled in the outer exozone.

REMARKS. Only two poorly preserved specimens of this species have been found at Clog-y-fran. The colonies are primarily recognised by the erect form, and by autozooecial walls that are thick throughout the colony. Autozooecial apertures are rounded-petaloid in transverse section and markedly petaloid in shallow tangential section. Rounded mesozooecia are common with abundant diaphragms; diaphragms are rare in the autozooecia. Acanthostyles are present throughout the colony; they are large and abundant in the exozone.

The identification of this species is difficult because of the poor quality of the two known specimens. *Leioclema* sp. A is placed in open nomenclature until better preserved material can be obtained and a complete description of this possibly new species can be made.

Leioclema sp. B — Fig. 11

MATERIAL. NHM PD 8306.

DESCRIPTION. Zoaria erect with very thin cylindrical branches, on average 1.5 mm in diameter.

Autozooecia curve away gradually from the branch axis in the endozone and then more abruptly in the exozone to meet the zoarial surface at 90°. Autozooecia within the endozone all have straight thin walls.

The exozone is extremely broad with an average width of 0.67 mm. It is recognised by a simultaneous thickening of zooecial walls and a change in zooecial orientation. Autozooecia all originate in the endozone where they are rounded in transverse section. They retain this shape in the exozone, as seen in tangential sections of branches. Autozooecial diameters average 0.09 mm by 0.11 mm within the exozone. Diaphragms are absent in the autozooecia. Occasional cystiphragms can, however, be found in the outer exozone.

Mesozooecia are common and originate in the inner parts of the exozone. They are rounded in shape in tangential sections and have a maximum diameter averaging 0.04 mm. The mesozooecia contain abundant orally deflected, thick, basal diaphragms, spaced on average 0.04 mm apart, and generally increasing in thickness distally along the mesozooecia.

Acanthostyles are common and have an average diameter of 0.03 mm and density of 29.5 per mm^2. They originate deep in the exozone, extend the length of the exozone, and are composed of a hyaline calcite core surrounded by steeply dipping conical laminae.

Autozooecial wall thickness averages 0.08 mm in the exozone. Wall microstructure is composed of steeply inclined, V-shaped laminae. The zooecial boundaries are, however, indistinct. Zooecia are frequently infilled with laminar calcite close to the zoarial surface. In longitudinal section this infilling consists of broad U-shaped laminae.

REMARKS. *Leioclema* sp. B is primarily characterised by: the small size of the erect branches; autozooecial apertures rounded in transverse section throughout the colony; an exozone which is very wide in comparison with the endozone; common rounded mesozooecia containing abundant diaphragms; and small but long acanthostyles. Only one specimen is known from Clog-y-fran. *Leioclema* sp. B can be distinguished from *Leioclema* sp. A by the smaller colony size.

Owen (1962, 1965, 1969) described numerous species of *Leioclema* and the related *Asperopora* from the Silurian of the Welsh Borderland and Shropshire. *L. halloporoides* Owen, 1962 was described from the Ludlow Aymestry Limestone of Shropshire. This also has very small colony branches (2 mm diameter) and mesozooecia containing diaphragms. *Leioclema* sp. B, however, has more abundant diaphragms within the mesozooecia and larger acanthostyles

Leioclema sp. B is possibly a new species but, as it is represented only by one poorly preserved specimen, no specific name will be assigned until further material is obtained.

Leioclema? sp. Figs 12–13

MATERIAL. NHM PD 8316–8318.

DESCRIPTION. Zoaria erect with thick cylindrical branches, on average 12 mm in diameter.

Autozooecia curve outwards gradually from the branch axis to meet the zoarial surface at 90°. The autozooecia within the endozone have very thick walls.

The exozone has an average diameter of 2.28 mm. It is recognised by a slight thickening of the zooecial walls. Autozooecia all originate in the endozone where they are rounded-polygonal in transverse section; they become irregular-rounded in the exozone, as seen in tangential sections of branches. Autozooecial diameters average 0.37 mm × 0.45 mm within the exozone. Thin basal diaphragms, which are orally-deflected at their junctions with the zooecial walls, are rare.

Mesozooecia occur in the exozone, on shallow tangential sections. They are rounded with a maximum diameter averaging 0.14 mm, and contain abundant, thick, orally-deflected, basal diaphragms, which are spaced on average 0.13 mm apart in the endozone and 0.1 mm in the exozone.

Acanthostyles are large and abundant with an average diameter of 0.09 mm and density of 12.5 per mm^2. They vary greatly in size, ranging in diameter from 0.05 mm to 0.12 mm, and originate throughout the colony. They are often wider than the zooecial walls. The acanthostyles are composed of a broad hyaline core; no sheathing laminae can be identified.

Autozooecial wall thickness averages 0.06 mm in the exozone. Wall microstructure is composed of inclined, V-shaped laminae, but is exceedingly poorly preserved.

REMARKS. Only three fragmentary specimens of this species have been found. The colonies are erect with thick autozooecial walls. The autozooecia are rounded-polygonal to slightly petaloid in shallow tangential section. Rounded mesozooecia are present and have abundant diaphragms. Diaphragms are rare in autozooecia. Acanthostyles are large and abundant throughout the colony, occasionally inflecting autozooecial walls.

Identification of the species is difficult because of the poor preservation of the material. The abundance of diaphragms in the mesozooecia and the lack of them in the autozooecia fit within the generic concept of *Leioclema* followed here. However, the acanthostyles are large (often wider than the zooecial walls), abundant and originate throughout the colony. A thick hyaline core is identifiable but no surrounding laminae are present, as found in the acanthostyles of other species of *Leioclema*. The acanthostyles are similar to those observed in the early Ordovician genus *Orbipora* Eichwald, 1856, illustrated in Astrova (1978: pl. ii, fig.i) and Taylor & Cope (1987: fig.1). *Orbipora* is, however, characterised by its massive form and absence of mesozooecia.

The precise taxonomic placing of the species is uncertain because of the poor quality of the material available. The specimens are therefore tentatively designated *Leioclema*? sp.

Family **HALLOPOROIDAE** Bassler, 1911
Genus ***HALLOPORA*** Bassler, 1911

Hallopora peculiaris Pushkin, 1987 Fig. 14

1987 *Hallopora wesenbergiana peculiaris* Pushkin *in* Ropot & Pushkin: 153; pl. 8, fig. 5, pl. 9, fig. 1.
1991b *Hallopora peculiaris* Pushkin; Buttler: 86; pl. 3, figs 3–8.

MATERIAL. NHM PD 8396.

OTHER OCCURRENCES. Piriguskii Stage (Lower Ashgill, upper Ordovician), Shikipi, Latvia (see Pushkin *in* Ropot & Pushkin, 1987), Slade and Redhill Beds (upper Rawtheyan, Ashgill), A40 Pengawse Hill diversion, W. of Whitland, Dyfed, Wales (SN 164170) (see Buttler 1991b).

DESCRIPTION. Zoarium erect with cylindrical branches on average 5.7 mm in diameter.

Autozooecia curve gradually away from the branch axis in the endozone and meet the zoarial surface at approximately 80–90°. In the endozone the zooecial walls are very thin.

The exozone, recognised by a thickening of the zooecial walls, has an average width of 1.52 mm. Autozooecia are circular in transverse section throughout the colony and average 0.29 mm in diameter in the exozone. Diaphragms are rare within the autozooecia and when present, usually occur closely spaced in the distal exozone. These basal diaphragms are orally-deflected at their junctions with the zooecial walls and their laminae are generally continuous with the zooecial linings. The average spacing between diaphragms is 0.17 mm in the exozone.

Mesozooecia are common throughout the whole zoarium, often originating in the inner parts of the endozone. Mesozooecial walls are thin in the endozone and thicken in the exozone. They are polygonal to polygonal-rounded in shallow tangential sections. Basal diaphragms are present throughout their length, spaced on average 0.1 mm apart in the endozone and 0.07 mm in the exozone. Diaphragms tend to increase in thickness distally along the mesozooecia. In some colonies mesozooecial walls are constricted at the position of the diaphragms, producing a slightly beaded appearance.

Autozooecial wall thickness averages 0.1mm in the exozone. Wall microstructure is composed of steeply inclined, V-shaped laminae. The precise contact between the zooecia is indistinct. The thickened exozonal diaphragms in the mesozooecia are also laminar and are continuous with the wall laminae.

Maculae composed of a concentration of mesozooecia can be recognised in thin sections.

REMARKS. *Hallopora peculiaris* is primarily characterised by the extensive beaded mesozooecia which originate in the inner endozone. The autozooecia are circular throughout the colony, and diaphragms are rare in the endozone, becoming more abundant in the outermost regions.

H. peculiaris has also been described from the Slade and Redhill Beds (Ashgill) of South Wales (Buttler, 1991b).

Hallopora aff. *wesenbergiana* (Dybowski, 1877). Fig. 15

MATERIAL. NHM PD 8310–8313.

DESCRIPTION. Zoaria erect with thick cylindrical branches, on average 11 mm in diameter.

Autozooecia are parallel to the branch axis in the inner endozone and then curve outwards gradually to meet the zoarial surface at 80°–90°. Within the endozone autozooecial walls are thin and straight.

The exozone is difficult to distinguish; it can be recognised by a slight thickening of the zooecial walls. Autozooecia all originate in the endozone where they are polygonal-rounded in transverse section, becoming circular in the exozone as seen in tangential sections of branches. Autozooecial diameters average 0.21 mm by 0.27 mm within the exozone. Diaphragms are very abundant throughout the autozooecia. In the endozone there are periodic concentrations of diaphragms which occur throughout the colony at the same level. Within the concentrations, diaphragms are spaced on average 0.1 mm apart; elsewhere they are spaced on average 0.6 mm apart. In the exozone, diaphragms are very abundant and on average spaced 0.11 mm apart. All the diaphragms are basal and orally-deflected at their junctions with the zooecial walls.

Mesozooecia are present, originating in the outer parts of the endozone and inner parts of the exozone. They are rounded in shallow tangential sections and have a maximum diameter averaging 0.1 mm. They contain abundant orally deflected basal diaphragms spaced on average 0.07 mm apart in the exozone.

Autozooecial wall thickness averages 0.03 mm in the exozone. The wall microstructure is poorly preserved but vague laminations can be recognised in one tangential section.

REMARKS. *Hallopora* aff. *wesenbergiana* (Dybowski, 1877) is characterised by the ramose colony form with thick branches. Thin-walled zooecia have rounded apertures in shallow tangential sections. Diaphragms are abundant throughout the whole colony and are periodically concentrated in bands, which possibly indicate periods of slow growth. Bassler (1911) illustrated *H. wesenbergiana* from the Wesenberg Limestone and Wassalen Beds (Caradoc) in Estonia. This material is similar to the Welsh; it has thin-walled autozooecia with abundant diaphragms, although these do not occur in bands. The banding, or lack of it, may not be a specific feature but may relate to an environmental influence acting on the colonies. The poor quality of the Welsh material does not allow a more precise specific identification.

Genus *BATOSTOMA* Ulrich, 1882

Batostoma clogyfranense sp. nov. Figs 16–18

HOLOTYPE. NHM PD 8362.

PARATYPES. NHM PD 8353–8361, 8363–8375.

NAME. After the type locality.

DIAGNOSIS. Colony small, ramose. Autozooecia curve out gradually from branch axis to zoarial surface. Autozooecial walls thin in endozone. Autozooecia polygonal-rounded in transverse section, circular in shallow tangential sections. Small polygonal-rounded mesozooecia present, originating in outer endozone. Diaphragms present in all zooecia. Acanthostyles small, abundant in exozone.

DESCRIPTION. Zoaria erect with narrow cylindrical branches, on average 3.9 mm in diameter.

Autozooecia curve out gradually from the branch axis to meet the zoarial surface at an angle of 70°–80°. The autozooecia within the endozone have thin walls.

The exozone is narrow with an average diameter of 0.8 mm; it is characterised by a thickening of the zooecial walls. Autozooecia originate in the endozone where they are polygonal-rounded in transverse section, becoming circular in the exozone as seen in tangential sections of branches. Autozooecial diameters average 0.15 mm by 0.18 mm in the exozone. Diaphragms are found throughout the autozooecia, although they are less common in the inner exozone. They are spaced on average 0.28 mm apart in the endozone, and 0.15 mm apart in the exozone. These basal diaphragms are all orally-deflected at their junctions with the zooecial walls and their laminae are continuous with the zooecial linings.

Mesozooecia are present and originate in the outer parts of the endozone. They are polygonal-rounded in shallow tangential sections with a maximum diameter which averages 0.09 mm. Orally-deflected basal diaphragms are found along the length of the mesozooecia, spaced on average 0.07 mm apart.

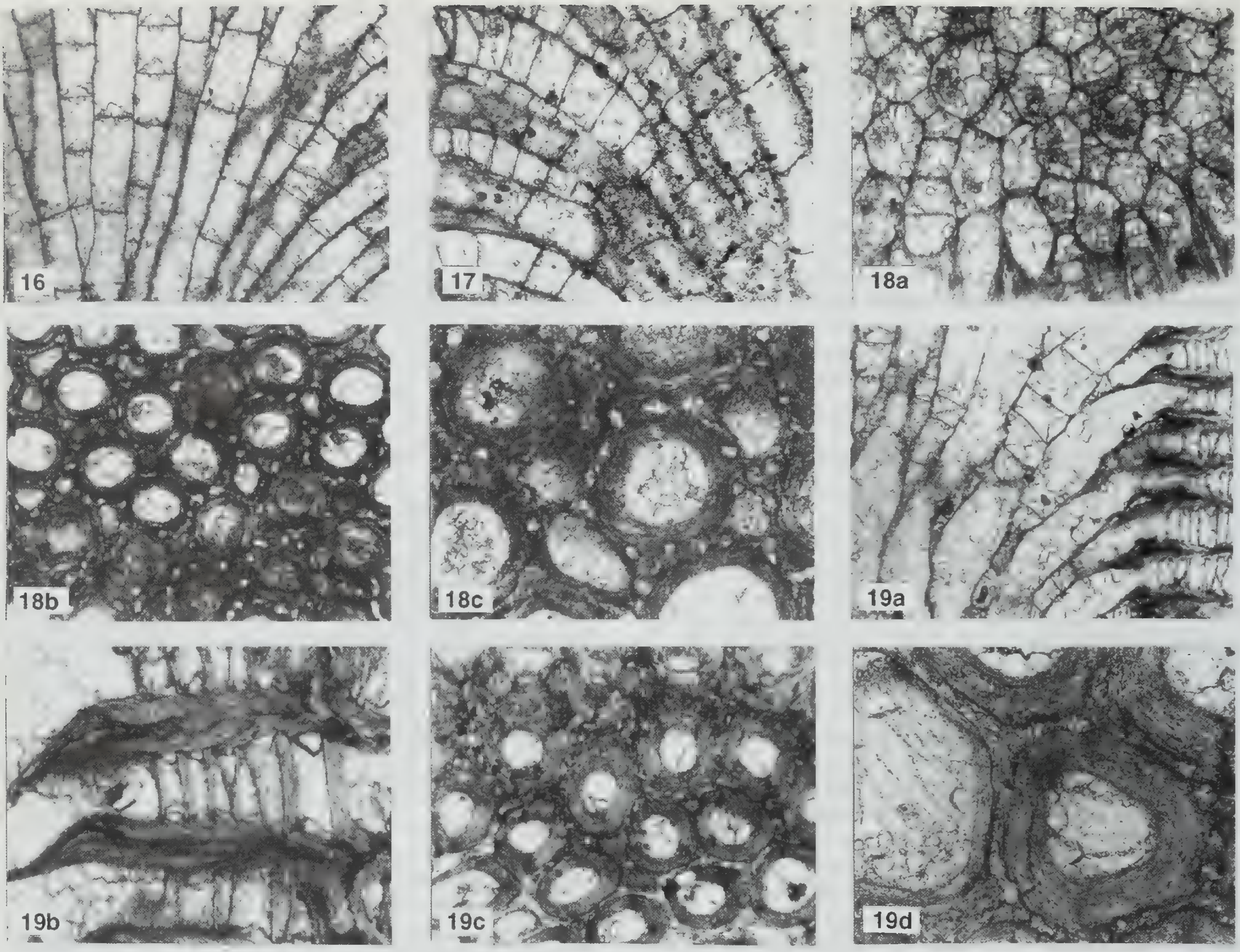
Acanthostyles are small, often irregularly shaped and highly abundant, with an average diameter of 0.03 mm and density of 67 per mm^2. They originate in the exozone and usually form a ring around the autozooecia, consisting of approximately ten acanthostyles. The acanthostyles are composed of a circular, or sometimes irregular hyaline core surrounded by indistinct dipping conical laminae.

Autozooecial wall thickness averages 0.08 mm in the exozone. Wall microstructure is composed of inclined, U-shaped laminae; however, it is poorly preserved. Frequently, zooecia are infilled with laminar calcite close to the colony surface; in longitudinal section this infilling consists of broad U-shaped laminae; large sections of zoaria often have all the zooecia infilled in this way.

REMARKS. *Batostoma clogyfranense* sp. nov. is primarily characterised by thin, straight zooecial walls, a narrow exozone, and diaphragms regularly spaced throughout the colony. Autozooecial apertures are rounded in shallow tangential section, and polygonal-rounded mesozooecia occur. Acanthostyles are abundant and occasionally irregular in shape.

Another species of *Batostoma*, *B.* cf. *polare* Astrova, 1965, that is described here can be distinguished from *B. clogyfranense* by the thicker exozonal walls and the less abundant diaphragms in the exozone.

The middle Ordovician species *B. subtile* Astrova (1965: pl. 50, fig. 2, pl. 51, fig. 1), from Vaigach Island, Novaya Zemlya, Russia, has a similar pattern of diaphragms within the endozone to *B. clogyfranense.* Diaphragms are, however, more abundant in the



Figs 16–18 *Batostoma clogyfranense* sp. nov. **16**, NHM PD 8362 (holotype), longitudinal section, x22. **17,** NHM PD 8374 (paratype), longitudinal section, x30. **18**, NHM PD 8362 (holotype); **18a**, transverse section, x30; **18b**, tangential section, showing infilled zooecia, x37; **18c**, tangential section, x86.
Fig. 19 *Batostoma* cf. *polare* Astrova 1965, NHM PD 8324; **19a**, longitudinal section, x22; **19b**, longitudinal section, x70; **19c**, tangential section, x41; **19d**, tangential section, x96.

exozone, and mesozooecia are less common in the Russian species.

Two species of *Batostoma* have been previously described from the Lower Palaeozoic of the Welsh Basin. *B. murchisoni* was described by Spjeldnaes (1957) from 'Horderley' in Shropshire. This species has few diaphragms and mesozooecia, and acanthostyles are absent, suggesting that the species may not belong to *Batostoma*. A re-examination of the type material is required. Owen (1962) described *Batostoma* sp, from the Aymestry Limestone (Ludlow Series, Silurian), Wenlock. This species has a very small exozone and mesozooecia are absent.

Batostoma **cf.** ***polare*** **Astrova, 1965** Fig. 19

MATERIAL. NHM PD 8324.

DESCRIPTION. Zoarium erect with narrow cylindrical branches, on average 4.5 mm in diameter.

Autozooecia are parallel to the branch axis within the endozone and curve abruptly outwards in the exozone to meet the zoarial surface at 90°. The autozooecia within the endozone have thin, slightly wavy walls.

The exozone is thick with an average diameter of 1.1 mm. It is recognised by an extensive thickening of the zooecial walls and a simultaneous change in zooecial orientation. Autozooecia all originate in the endozone, where they are polygonal-rounded in transverse section. They become circular in the exozone, as seen in tangential sections of branches. Autozooecial diameters average 0.16 mm by 0.2 mm within the exozone. Diaphragms are present throughout the autozooecia, spaced on average 0.06 mm apart in the endozone and increasing greatly to 0.38 mm apart in the exozone. The majority of these are basal diaphragms, which are deflected orally at their junctions with the zooecial walls. Successive diaphragms increase in thickness distally along the autozooecia. Several subterminal, aborally deflected diaphragms have been recognised at the distal end of the colony.

Mesozooecia are present, although not abundant, and originate in the inner parts of the exozone. They have a maximum diameter averaging 0.1 mm. In shallow tangential sections they are rounded. The mesozooecia contain abundant, thick, orally deflected, basal diaphragms, which are spaced on average 0.05 mm apart.

Acanthostyles are small and abundant with an average diameter of 0.02 mm and density of 30 per mm^2. They originate in the exozone and usually form a ring around the autozooecia, approximately 14 acanthostyles surrounding one autozooecium. The acanthostyles have a hyaline core surrounded by steeply dipping conical laminae.

Autozooecial wall thickness averages 0.11 mm in the exozone. Wall microstructure is composed of steeply inclined, V-shaped laminae. Zooecial boundaries are dark, crenulated and granular. Some zooecia are infilled with laminar calcite close to the colony surface. In longitudinal section this infilling consists of broad U-shaped laminae.

An intrazoarial overgrowth has been recognised which is continuous with the underlying branch and is composed of outer endozonal/ inner exozonal components.

REMARKS. Only one specimen of *Batostoma* cf. *polare* Astrova, 1965, has been found during this study. It is characterised by the ramose colony form and particularly thin autozooecial walls in the endozone, which thicken extensively in the exozone. Autozooecial apertures are circular in shallow tangential sections, and rounded mesozooecia, which originate in the outer endozone, are present. Thick diaphragms are abundant in the exozone and thin diaphragms occur in the endozone. Acanthostyles are small and numerous in the exozone.

B. polare Astrova, 1965, described from the Varnek Stage, Vaigach and Novaya Zemlya, Russia, is very similar to the specimen from Clog-y-fran. They both have thin zooecial walls in the endozone which thicken in the exozone, abundant basal exozonal diaphragms, small mesozooecia and acanthostyles. Measurements for the Soviet and Welsh specimens are similar. The major difference between the Welsh specimen and type *B. polare* is the presence of the diaphragms within the endozone of the former.

Genus ***ERIDOTRYPA*** Ulrich, 1893

Eridotrypa simulatrix (Ulrich, 1890) Fig. 20

1890 *Batostoma simulatrix* Ulrich; 432, pl. 35, fig. 1.
1893 *Monticulopora simulatrix* (Ulrich); James: 194.
1908 *Eridotrypa simulatrix* (Ulrich); Cummings: 828, pl. 16, fig. 4.
1928 *Eridotrypa simulatrix* (Ulrich); Bassler: 152
1987 *Eridotrypa simulatrix* (Ulrich); Ropot & Pushkin: 171, pl. 15, fig. 2.

MATERIAL. NHM PD 8342–8352.

OTHER OCCURRENCES. Cincinnati Group, Savanna, Illinois, USA; English Head and Vaureal Formations, Anticosti Island, Quebec, Canada; Waynesville Formation, Harmons Station, Indiana, USA; Pirguskii Stage (Caradoc), Yuzhnoi, Pribaltiki, Russia.

DESCRIPTION. Zoaria erect with narrow cylindrical branches, on average 3.3 mm in diameter.

Autozooecia meander roughly parallel to the branch axis within the endozone and then curve slightly in the exozone to meet the zoarial surface at 50°. Within the endozone they have thin walls.

The exozone is narrow with an average diameter of 0.64 mm. It is recognised by an extensive thickening of the zooecial walls. Autozooecia all originate in the endozone and are rounded-polygonal in transverse section, becoming oval-rounded in the exozone as seen in tangential sections of branches. In branch transverse section the autozooecia are larger in diameter in the inner endozone than in the outer endozone. Autozooecial diameters average 0.13 mm by 0.18 mm within the exozone. Diaphragms are occasionally present in the endozone and exozone, spaced on average 0.35 mm apart in the endozone and 0.13 mm in the exozone. In some specimens they are very abundant (PD 8348). These basal diaphragms are all deflected orally at their junctions with zooecial walls and their laminae are continuous with the zooecial linings.

Mesozooecia are present and originate in the endozone. They are rounded in shallow tangential section, with a maximum diameter averaging 0.09 mm. Abundant orally deflected diaphragms are found along the length of the mesozooecia, spaced on average 0.07 mm apart.

Acanthostyles are small, occasionally irregular, abundant, with an average diameter of 0.02 mm. They are composed of a hyaline calcite core surrounded by indistinct dipping conical laminae.

Autozooecial wall thickness averages 0.06 mm in the exozone. Wall microstructure is rather indistinct (only peels of these specimens are available) and is composed of steeply inclined, V-shaped laminae. Zooecial boundaries have not been distinguished. Autozooecia, and more especially mesozooecia, are frequently infilled with laminar calcite close to the zoarial surface. In longitudinal section this infilling consists of broad V-shaped laminae; large areas of the colony can be infilled.

REMARKS. *Eridotrypa simulatrix* is characterised by the ramose colony with narrow branches. Autozooecial walls are thin and meandering in the endozone and thicken in the exozone. Autozooecial apertures are large and rounded/polygonal in transverse section, and small and oval in shallow tangential section. Diaphragms are present and abundant small acanthostyles occur in the exozone.

It is not easy to compare the Russian and American specimens of *E. simulatrix* because those from North America are only illustrated by line drawings. The Welsh and Russian specimens appear to be identical but together may prove to represent a distinct species from the American specimens when direct comparisons have been made using the actual material.

Genus ***MONTICULIPORA*** d'Orbigny, 1850

Monticulipora* aff. *compacta Coryell, 1921. Fig. 21

MATERIAL. NHM PD 8328, 8331c.

DESCRIPTION. Zoaria erect with narrow cylindrical branches, on average 4 mm in diameter.

Autozooecia curve out gradually from the branch axis in the endozone and meet the zoarial surface at 90°. The autozooecia within the endozone have thin, slightly wavy walls.

The exozone is moderately broad with an average width of 1.05 mm. It is recognised by a thickening of the zooecial walls. Autozooecia all originate in the endozone, where they are circular in transverse section. They become rounded in the exozone as seen in tangential sections of branches. Autozooecial diameters average 0.16 mm by 0.13 mm within the exozone. Diaphragms are present throughout the autozooecia. They are spaced on average 0.15 mm apart in the endozone and increase to 0.07 mm apart in the exozone. The majority of the diaphragms are basal, deflected orally at their junctions with the autozooecial walls. Some diaphragms are possibly subterminal, but the poor preservation of the specimen does not allow this to be confirmed. Cystiphragms are numerous along the whole length of the autozooecia, especially in the exozone. The cystiphragms are normally restricted to one side of an autozooecium.

Mesozooecia are uncommon, and originate in the outer parts of the endozone and inner parts of the exozone. They have an average maximum diameter of 0.08 mm, are rounded in shallow tangential section and contain abundant, orally deflected basal diaphragms.

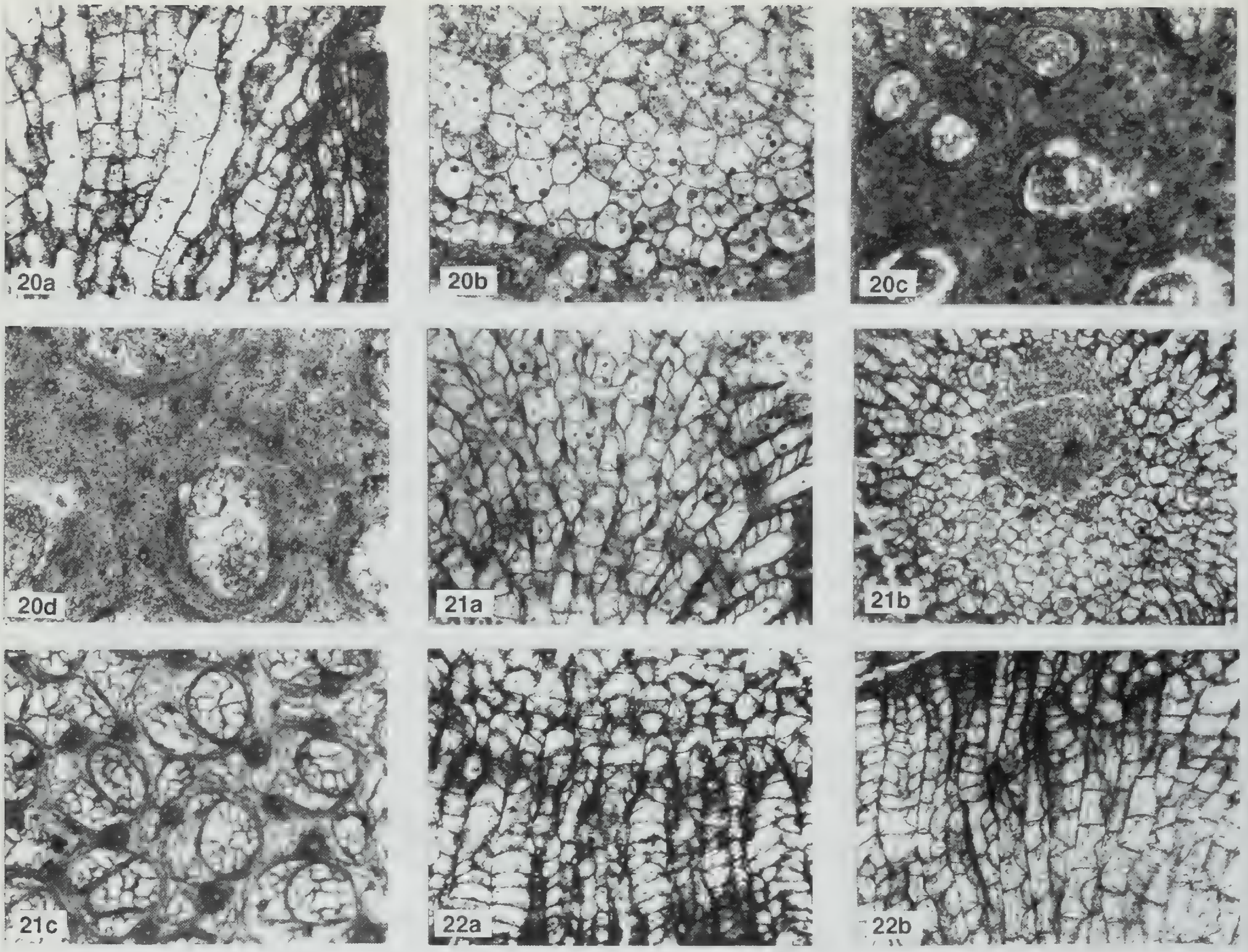


Fig. 20 *Eridotrypa simulatrix* (Ulrich, 1890), NHM PD 8343; **20a**, longitudinal section, x25; **20b**, transverse section, x25; **20c**, tangential section, x53; **20d**, tangential section, x103.

Fig. 21 *Monticulipora* aff. *compacta* Coryell, 1921, NHM PD 8328; **21a**, longitudinal section, x30; **21b**, transverse section, x22; **21c**, tangential section, x86.

Fig. 22 *Homotrypa* cf. *similis* Foord 1883, NHM PD 8323; **22a**, longitudinal section, x30; **22b**, transverse section, x30.

Acanthostyles are abundant with an average diameter of 0.03 mm and density of 47 per mm^2. They originate throughout the whole colony and occasionally indent autozooecial apertures. The acanthostyles are composed of a hyaline calcite core surrounded by steeply dipping conical laminae.

Autozooecial wall thickness averages 0.05 mm in the exozone. Wall microstructure is composed of steeply inclined, V-shaped laminae. It is, however, indistinct due to the presence of the acanthostyles. Occasional zooecia are infilled with laminar calcite close to the zoarial surface. In longitudinal section this infilling consists of broad U-shaped laminae.

REMARKS. This species is characterised by the ramose colony form and autozooecial apertures which are rounded in shallow tangential section. Zooecial walls are thin in the endozone, thickening in the exozone. Diaphragms and/or cystiphragms occur in the autozooecia, while the mesozooecia contain only diaphragms. Acanthostyles are abundant throughout the colony. This is the only species of *Monticulipora* encountered in the present study and the material is poorly preserved and visible only in section.

Monticulipora compacta Coryell, 1921, described from the Pierce Limestone (Caradoc), Tennessee, USA (Coryell 1921: 283), Novaya Zemlya, Vaigach, and Stodolbskgo (middle Ordovician), Zapadno-Arkticheska Province, Russia (Astrova 1965: 197), has a pattern of diaphragms and cystiphragms, and rare mesozooecia similar to the Welsh specimens. In tangential section (Coryell, 1921: pl. iv, fig. 6) the autozooecial apertures are polygonal-rounded. This figured section is, however, quite deep and so cannot be accurately compared with the shallow Welsh sections. In *M. compacta* acanthostyles are reported from within the axial region, but they are not identified from the exozone, in contrast to the Welsh material. The specimens described herein are therefore assigned to *M.* aff. *compacta* until better preserved material can be examined.

Genus *HOMOTRYPA* Ulrich, 1882

Homotrypa cf. *similis* Foord, 1883 — Fig. 22

MATERIAL. NHM PD 8323.

DESCRIPTION. Zoarium erect with cylindrical branches, on average 8 mm in diameter.

Autozooecia are roughly parallel to the branch axis within the endozone, and gradually curve outwards to meet the zoarial surface at approximately 70°. Walls are thin and slightly wavy within the endozone.

The exozone has an average diameter of 1.6 mm, and is recognised by a slight thickening of the zooecial walls. The autozooecia originate within the endozone, where they are polygonal in transverse section. No tangential sections are available. Diaphragms are present throughout the autozooecia. They are spaced on average 0.26 mm apart in the endozone and 0.1 mm apart in the exozone. The diaphragms are basal and are orally deflected at their junctions with the zooecial walls. Many diaphragms in the endozone are inclined and some are sigmoidal. Cystiphragms are numerous in the exozone where there are, on average, ten present per mm. The cystiphragms are normally restricted to one side of the autozooecia.

Mesozooecia are rare and originate in the exozone when present, with an average maximum diameter of 0.08 mm. They contain abundant orally deflected basal diaphragms, spaced on average 0.04 mm apart.

Small inconspicuous acanthostyle-like structures have been observed in the exozone; tangential sections are needed for their precise identification.

Autozooecial wall thickness averages 0.04 mm in the exozone. Wall microstructure is composed of inclined V-shaped laminae. The zooecial boundaries are dark and crenulated. Some zooecia are infilled close to the zoarial surface. In longitudinal section this infilling consists of broad U-shaped laminae.

REMARKS. Only one incomplete specimen of *Homotrypa* has been found in this present study; this has made identification difficult, especially as no tangential section could be obtained. The specimen is characterised by thin autozooecial walls in the exozone and rare mesozooecia. The autozooecia contain abundant diaphragms, especially in the exozone, often sigmoidal in shape in the endozone. Cystiphragms are extremely numerous in the exozone.

Ross (1963, 1965) described three Ordovician species; *Homotrypa* sp. A, *Homotrypa* sp. B and *H. oweni* from the Hoar Edge Group (Caradoc Series), Shropshire. *Homotrypa* sp. A of Ross (1963) has widely spaced diaphragms and cystiphragms; mesozooecia and dense acanthostyles are present but not always easy to observe in tangential section. The autozooecial apertures are polygonal to subpolygonal in shallow tangential sections. *Homotrypa* sp. B of Ross (1963) has thin autozooecial walls within the endozone and subpolygonal zooecial apertures. Diaphragms are present throughout the colony and acanthostyles are long and thin. The specimen from Clog-y-fran differs from *Homotrypa* sp. A in having more abundant diaphragms and cystiphragms; and from *Homotyrpa* sp. B by the absence of long thin acanthostyles. *Homotrypa oweni* Ross, 1965 differs from the Clog-y-fran specimen in having a cone-shaped or encrusting colony form, mesozooecia and rare diaphragms.

The arrangement of the cystiphragms and diaphragms in the Welsh specimen is similar to that found in *Homotrypa similis* Foord, 1883 (e.g. Karklins 1984: pl. 5, figs 2, 3). This species is well known in North America and Eastern Europe. *H. similis* has acanthostyles in the exozone but in the specimen from Clog-y-fran their presence is questionable. Bork & Perry (1968: 1053) recognised *H. similis* (from the Guttenberg and Ion Formations, middle Ordovician, Iowa, USA) in longitudinal section 'by extremely gradual curvature of the zooecia towards the zoarial surface, diaphragms throughout most of the axial region and well-developed cystiphragms and diaphragms in the mature zone'; the Welsh specimen fits this description.

Karklins (1984: 29) noted a difference between specimens of *H. similis* from the Trenton Beds (middle Ordovician), Ottawa, Canada, and the Lexington Limestone (middle/upper Ordovician), Kentucky, USA, and those from the Wassalen Beds (Caradoc) of Estonia (described by Bassler 1911). Specimens from Estonia have relatively broadly serrated autozooecial boundaries and well-defined acanthostyles which commonly indent the autozooecial apertures. North American specimens have narrower serrated boundaries and poorly-defined acanthostyles. The cystiphragms in the Estonian specimens are more closely spaced in the exozone that those of North America. Middle Ordovician specimens from Vaigach Island in Russia, illustrated by Astrova (1965: pl. 35), do not, however, have large acanthostyles, and their cystiphragms first occur in the outer endozone and become closely-spaced in the exozone. Thus, there appears to be a wide range of variation within the species *H. similis*.

The Clog-y-fran specimen is compared herein with *H. similis* rather than positively identified as this species because the incomplete specimen does not provide sufficient information.

Genus ***MONOTRYPA*** Nicholson, 1879

Monotrypa sp. Figs 23–24

MATERIAL. NHM PD 8329, 8330.

DESCRIPTION. Zoaria hemispherical, on average 13.5 mm in diameter.

The majority of autozooecia originate from the basal lamina and curve gently outwards to meet the zoarial surface. Autozooecial walls are straight throughout the colony. No differentiation between endozone and exozone can be recognised. The autozooecia are polygonal-rounded in transverse section, with an average diameter of 0.29 mm by 0.32 mm. Diaphragms are rare, usually only one per autozooecium. In one specimen (PD 8329), however, there is a small area of the colony with relatively numerous diaphragms which are thin, basal and orally deflected at their junctions with the zooecial walls.

Autozooecial wall thickness averages 0.02 mm at the periphery of the colony. Wall microstructure is composed of inclined U-shaped laminae; the zooecial boundaries are indistinct. Occasionally zooecia are infilled with laminar calcite close to the zoarial surface. In longitudinal section this infilling consists of broad U-shaped laminae.

REMARKS. The specimens described herein are characterised by the hemispherical colony form and polygonal-rounded autozooecia. Autozooecial walls are thin and straight, with no differentiation between endozone and exozone. Diaphragms are generally uncommon. Only two specimens are known, both in peels.

Several species of *Monotrypa* with thin straight walls and sparse diaphragms have previously been described, e.g. *M. testudiformis* and *M. cantarelloidea* described by Dreyfuss (1948: pl. 2, figs 4, 5, 8–10) from the upper Ordovician of the Montagne Noire.

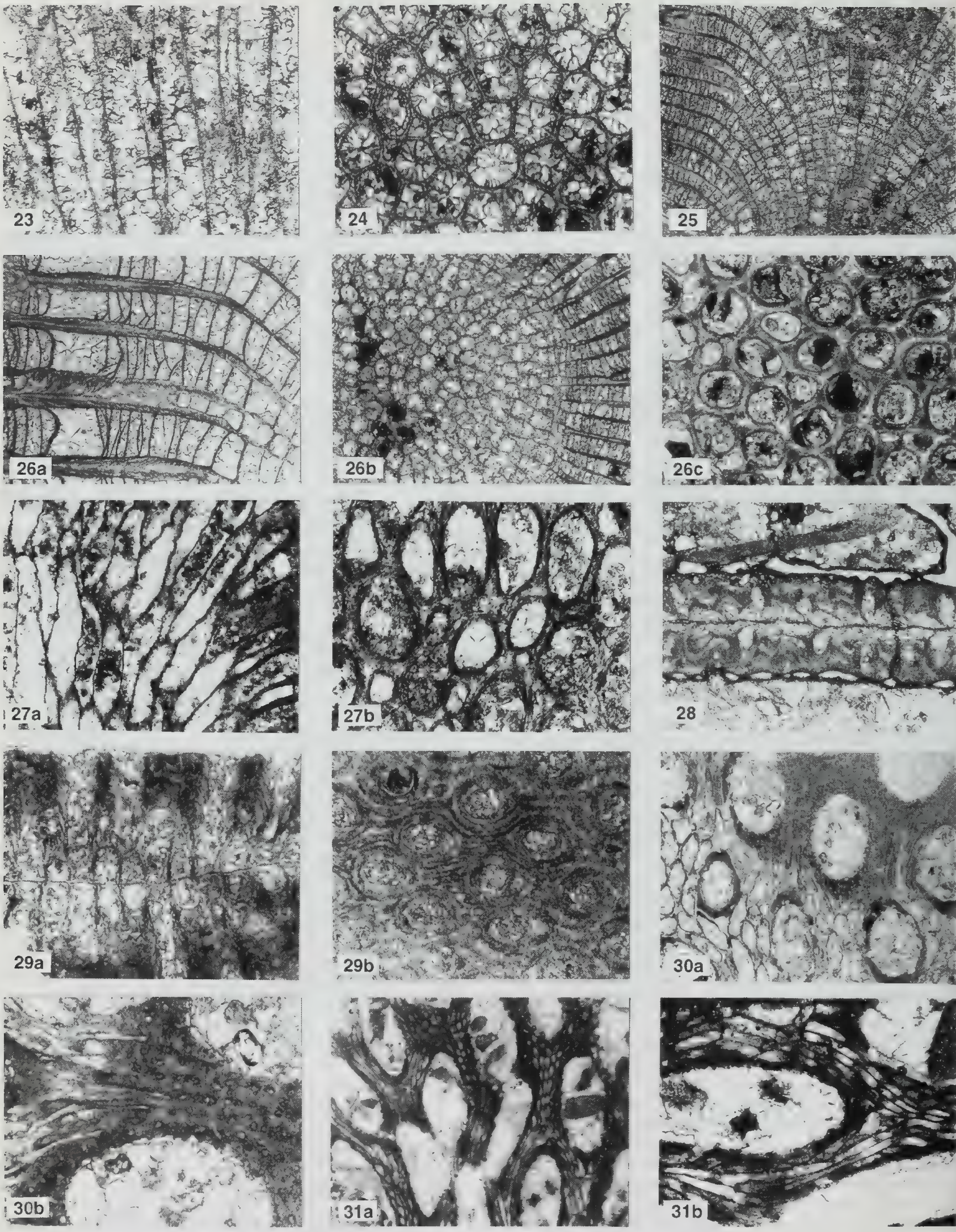
The poor quality of the Welsh specimens prevents detailed comparisons with other species, so their identification is left in open nomenclature.

Genus ***AMPLEXOPORA*** Ulrich, 1882

Amplexopora sp. Figs 25–26

MATERIAL. NHM PD 8325, 8326.

DESCRIPTION. Zoaria erect with thick cylindrical branches, on average 8 mm in diameter.


23
24
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26a
26b
26c
27a
27b
28
29a
29b
30a
30b
31a
31b

Autozooecia curve out gradually from the branch axis in the endozone and change direction abruptly in the exozone to meet the colony surface at 90°. Autozooecia within the endozone all have very thin walls.

The exozone is wide, with an average diameter of 1.9 mm. It is recognised by a thickening of the zooecial walls and a simultaneous change in zooecial orientation. Autozooecia all originate in the endozone where they are rounded in transverse section, becoming irregularly rounded in the exozone as seen in tangential sections of the branches. Autozooecial diameters average 0.24 mm by 0.3 mm within the exozone.

Diaphragms are very abundant and closely spaced along the whole length of the autozooecia. They are spaced on average 0.23 mm apart in the endozone, decreasing to 0.09 mm apart within the exozone. All diaphragms are basal and are orally deflected at their junctions with the zooecial walls. In the mid exozone of specimen PD 8325 there is a large interval (0.34 mm) between two adjacent diaphragms, which is found in the same position throughout the colony. The first diaphragms on the distal side of this interval are greatly deflected orally. In the majority of the colony, growth resumes as normal after the interval; however, in some small sections the thickened exozonal wall terminates and is replaced by one much thinner.

Mesozooecia are present, although not abundant, and have a maximum diameter averaging 0.12 mm. They originate in the exozone, are oval in shape in shallow tangential sections, and contain abundant orally deflected basal diaphragms, spaced on average 0.05 mm apart.

Acanthostyles are large and abundant, with an average diameter of 0.05 mm and density of 14 per mm^2. They originate throughout the exozone, commonly extending the entire length of the exozone, and can slightly indent the zooecial apertures. The acanthostyles are composed of a hyaline core surrounded by steeply dipping conical laminae.

Autozooecial wall thickness averages 0.08 mm in the exozone. Wall microstructure is composed of inclined U-shaped laminae. Zooecial boundaries are indistinct. Some zooecia (especially mesozooecia) are infilled with laminar calcite close to the zoarial surface; in longitudinal section this infilling consists of broad U-shaped laminae.

REMARKS. This species is characterised by the ramose colony form, thin autozooecial walls and rounded apertures in shallow tangential section. Oval mesozooecia are present and originate in the outer endozone/inner exozone. Basal diaphragms are abundant throughout the colony, and large acanthostyles are abundant in the exozone.

Three species of *Amplexopora* have been previously described from the Welsh Basin. All were described by Ross (1963, 1965) from the Hoar Edge Limestone, Hoar Edge Group (Caradoc), Evenwood Quarry, Shropshire, and all vary markedly from the species described herein. *A. thomasi* Ross, 1963 is a bifoliate species with small acanthostyles and lacking diaphragms in the endozone. *A*? *evenensis* Ross, 1965 and *Amplexopora*? sp. A of Ross, 1965 both have crenulate walls, diaphragms confined to the exozone and small acanthostyles.

The specimens of *Amplexopora* from Clog-y-fran are similar to *A. septosa* (Ulrich, 1879) (redescribed by Boardman 1960) from the Fairview Formation (Ashgill), Covington, Kentucky. The major differences in *A. septosa* are the absence of diaphragms in the endozone and the presence of numerous short, off-set acanthostyles, as well as the long acanthostyles which occur throughout the exozone. Off-set acanthostyles can be identified in specimen PD 8326, but have not been recognised in PD 8325.

Other examples of *Amplexopora* containing abundant diaphragms in the endozone have been described by Brown & Daly (1985) from the Dillsboro Formation (Cincinnati Series) of SE Indiana; they were identified as *A.* cf. *septosa*. Numerous specimens (over 150) of *A. septosa* were collected from this formation, including a few atypical specimens with abundantly spaced diaphragms in the endozone. Brown & Daly (1985: 24) suggested that because the specimens were similar in all other respects to *A. septosa* the differences may be due to environmental factors. The specimens from Clog-y-fran are very similar to those from the Dillsboro Formation, except that the short acanthostyles are less common and the diaphragms more abundant.

Genus *HALLOPORINA* Bassler, 1911

Halloporina cf. *crenulata* (Ulrich, 1893) Fig. 27

MATERIAL. NHM PD 8315, 8394.

DESCRIPTION. Zoaria erect with cylindrical branches, on average 4.5 mm in diameter.

Autozooecia are parallel to the branch axis within the endozone and then curve outwards gradually in the exozone to meet the zoarial surface at 70°. The autozooecia within the endozone have very thin wavy walls.

The exozone is narrow with an average diameter of 0.76 mm. It is recognisable by a thickening of the zooecial walls and a simultaneous change in zooecial orientation. Autozooecia all originate in the endozone where they are polygonal-rounded in transverse section, becoming oval-rounded in the exozone, as seen in tangential sections of branches. Autozooecial diameter averages 0.18 mm by 0.22 mm within the exozone. Basal diaphragms are rare or even wholly absent in the autozooecia and, if present, only one or two are found in the exozone. They are all deflected orally at their junctions with the zooecial walls and their laminae are continuous with the autozooecial linings.

Exilazooecia are present and originate in the exozone. They are rounded in shape in shallow tangential sections, with a maximum diameter averaging 0.08 mm. They occasionally contain orally

Figs 23, 24 *Monotrypa* sp. **23,** NHM PD 8330; longitudinal section, x30. **24**, NHM PD 8329; tangential section, x30.

Fig. 25 *Amplexopora* sp., NHM PD 8325; longitudinal section, x12.

Fig. 26 *Amplexopora* sp., NHM PD 8325; **26a,** longitudinal section, showing large interval between adjacent diaphragms, x35; **26b**, transverse section, x12; **26c**, tangential section, x30.

Fig. 27 *Halloporina* cf. *crenulata* (Ulrich 1893), NHM PD 8315; **27a**, longitudinal section, x22; **27b**, tangential section, x61.

Figs 28, 29 *Graptodictya bonnemai* Bassler 1911. **28**, NHM PD 8392b, longitudinal section, x30. **29**, NHM PD 8389; **29a**, transverse section, x55; **29b**, tangential section, x55.

Fig. 30 *Pushkinella* sp., NHM PD 8376; **30a**, tangential section, x22; **30b**, tangential section, x53.

Fig. 31 *Phylloporina* sp., NHM PD 8384; **31a**, tangential section, x12; **31b**, tangential section, x22.

deflected basal diaphragms, and are therefore mesozooecia (*sensu stricto*), but the term exilazooecia is retained for consistency with the genus description.

Autozooecial wall thickness averages 0.05 mm in the exozone. Wall microstructure is composed of steeply inclined, V-shaped laminae; the zooecial wall boundaries are dark and granular. Some exilazooecia are infilled with laminar calcite close to the zoarial surface. In longitudinal section this infilling consists of broad U-shaped laminae.

REMARKS. *Halloporina crenulata,* the type species of the genus, has been described from the Black River and Trenton Formations (middle Ordovician) of the U.S. mid-west but has not been recognised elsewhere. Only one other species of *Halloporina* has hitherto been identified: *H. parva* (Ulrich & Bassler, 1904), also from the Black River and Trenton Formations of the U.S. mid-west. *H. crenulata* is distinguished from *H. parva* in having a larger zoarium, larger rounded zooecial apertures (*H. parva* has polygonal zooecial apertures) and more abundant exilazooecia. Nothing is known about the range of variation within either species of *Halloporina*. Ulrich & Bassler (1904: pl. xiv) illustrated the two species. Colony size appears to be the only major difference between them as shown in the illustrations. The drawings indicate little difference in zooecial aperture shape; the tangential section of *H. crenulata* is, however, deeper than in *H. parva.* A re-examination of the species and further material, is needed for a greater understanding of these species.

The specimens from Clog-y-fran are identified only as *H.* cf. *crenulata.* The identification is tentative due to the presence of occasional diaphragms within the outer exozone. The rounded zooecia and relatively abundant exilazooecia suggest similarity to *H. crenulata* rather than *H. parva.*

Order **CRYPTOSTOMATA** Vine, 1884
Suborder **PTILODICTICTYINA** Astrova & Morozova, 1956
Family **ESHAROPORIDAE** Karklins, 1983
Genus ***GRAPTODICTYA*** Ulrich, 1882

Graptodictya bonnemai Bassler, 1911 — Figs 28–29

1911 *Graptodictya bonnemai* Bassler: 122, pl. 8, fig. 3, text-fig. 48.
1921 *Graptodictya bonnemai jaervensis* Bekker: 58, pl. 8, figs 1–4.
1952 *Graptodictya bonnemai* Bassler; Toots: 126, pl. 7, figs 5, 8, pl. 8, fig. 3, pl. 9, figs 1, 2, pl. 10, fig. 1.
1965 *Graptodictya bonnemai* Bassler; Astrova: 2252, pl. lx, fig. 2, pl. lxi, fig. 1.
1970 *Graptodictya bonnemai* Bassler; Nekhorosheva: 86, pl. viii, fig. 1.

MATERIAL. NHM PD 8389–8391, 8392b, 9393.

OTHER OCCURRENCES. Kuckers Shale (Kukruse Stage, Llandeilo), Baron Toll's Estate, Estonia; Jarve, Kukersite Quarry, Wesenberg Limestone (Kukruse Stage, Llandeilo), Wesenberg, Estonia; Vaigach Island and Pai-khoi (Yugorskiy Stage, Llandeilo/Caradoc), Urals, Russia.

DESCRIPTION. Zoaria erect with thin branches, on average 1.85 mm wide by 0.69 mm deep. The margins of the branches are striated.

Mesothecae are thin and sinuous. In the exozone the autozooecia form 90° angles with the mesothecae. Autozooecial apertures are oval in shallow tangential sections and average 0.48 mm by 0.3 mm in the exozone. Short superior hemisepta are commonly present. Autozooecial boundaries are slightly serrated. Zooecial wall microstructure is composed of broadly U-shaped laminae. Exilazooecia and diaphragms are absent.

REMARKS. *Graptodictya bonnemai* was first described by Bassler (1911: 122) from Estonia, as being very similar to the type species of *Graptodictya* (*G. perelegans*). The two species were distinguished by *G. bonnemai* branching less frequently and having more elongate autozooecial apertures.

Order **FENESTRATA** Elias & Condra, 1957
Suborder **PHYLLOPORININA** Lavrentjeva, 1979
Family **ENALLOPOROIDAE** Miller, 1889
Genus ***PUSHKINELLA*** Lavrentjeva, 1979

Pushkinella sp. — Fig. 30

MATERIAL. NHM PD 8376–8378, 8380–8383.

DESCRIPTION. Zoaria are reticulate and anastomosing; only fragmentary specimens have been found at Clog-y-fran. No exterior frontal views of the colonies are available because frontal surfaces are all embedded in sediment.

Fenestrules are oval-rounded, with diameters averaging 0.58 mm by 0.42 mm. Branches are rounded and average 0.38 mm diameter.

The exozone is distinguished by a change in the orientation of the autozooecia and considerable thickening of the zooecial walls. Autozooecia are rounded in the endozone, becoming rounded-slightly petaloid in the exozone, where they average 0.16 mm in diameter. Across one branch one to three autozooecia are present.

Wall microstructure is hard to distinguish. In one specimen (PD 8378) longitudinal laminar microstructure can be identified. Short, narrow acanthostyles are abundant throughout the colony; in the exozone they occasionally indent the autozooecial apertures. The acanthostyles are composed of a hyaline core surrounded by conical laminae, and are on average 0.1 mm in diameter.

REMARKS. The genus *Pushkinella* was previously known only from the Baltic region of the former Soviet Union. Two Ordovician species have been recognised: *P. mirabilis* Lavrentjeva 1979, and *P. robusta* Lavrentjeva 1979, from Estonia, and one Silurian, *P. acanthroporoides* Pushkin 1976, from Byelorussia.

The Welsh specimens of *Pushkinella* are characterised by the anastomosing colony form, the small oval-rounded fenestrules and rounded branches. Autozooecial walls are extensively thickened in the exozone and autozooecial apertures are rounded to slightly petaloid. Short and narrow acanthostyles are abundant.

The Welsh specimens differ from *P. robusta* in having more zooecial apertures per branch, and from *P. acanthroporoides* in having a greater number of acanthostyles. *P. mirabilis* has similar-sized apertures and acanthostyles to the Welsh material, but differs in having occasional basal diaphragms, which are absent in the Welsh specimens.

Family **PHYLLOPORINIDAE** Ulrich, 1890
Genus ***PHYLLOPORINA*** Foerste, 1887

Phylloporina sp. — Fig. 31

MATERIAL. NHM PD 8384.

DESCRIPTION. Zoaria are reticulate and anastomosing, only fragmentary specimens have been found at Clog-y-fran. No exterior frontal views of the colonies are available because frontal surfaces are all embedded in sediment.

Fenestrules are oval, with diameters averaging 0.78 mm by 1.67 mm. Branches are rounded and average 0.48 mm diameter. The reverse side of the colony is striated.

The exozone is distinguished by a change in the orientation of the autozooecia and a thickening of the zooecial walls. Rounded zooecial apertures are present on the frontal side of the colony. The apertures average 0.09 mm by 0.12 mm in diameter in the exozone. Three to four zooecial rows occur on each branch.

Zooecial walls are thin and straight. Occasional basal diaphragms have been observed which are deflected orally at their junction with the zooecial walls and in some cases have laminae continuous with the zooecial linings.

The microstructure is laminar, although hard to distinguish. Possible acanthostyle-like structures are present.

REMARKS. The specimen from Clog-y-fran is fragmentary and embedded in sediment, which makes identification difficult. It is characterised by rounded branches and oval fenestrules. Zooecial walls are straight in the endozone, becoming thickened in the exozone. Zooecial apertures are rounded and three to four rows occur on each branch. Occasional diaphragms are present and acanthostyle-like structures have been recognised.

Phylloporina hillistensis, described from Estonia by Lavrentjeva (1985: pl. iii, fig. 2), has similar thick straight endozonal walls and occasional diaphragms but differs from the Clog-y-fran specimen in having more abundant zooecia per branch and lacking striae on the reverse of the colony.

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TREPOSTOME IDENTIFICATION KEY

In order to identify trepostome bryozoans from Clog-y-fran thin sections are needed. Ideally at least two oriented sections (longitudinal and tangential) are required. However, specimens can sometimes be identified from randomly oriented sections. Identification can be hindered when specimens are fragmented and abraded. The key aims to aid identification, but results should be carefully checked against the complete descriptions and the illustrations of the species.

1. Zoaria massive and hemispherical 2
   Zoaria erect 3

2. Ring diaphragms present .... *Hemiphragma* sp
   Ring diaphragms and mesozooecia absent .... *Monotrypa* sp

3. Hemiphragms present 4
   Hemiphragms absent 5

4. Mesozooecia abundant with numerous diaphragms along their length .... *Dittopora sanclerensis*
   Mesozooecia present, but not common .... *Hemiphragma pygmaeum*

5. Cystiphragms present 6
   Cystiphragms absent 7

6. Abundant acanthostyles present .... *Monticulipora* aff. *compacta*
   Small indistinct acanthostyles present .... *Homotrypa* cf. *similis*

7. Acanthostyles present 8
   Acanthostyles absent 15

8. Diaphragms rare in autozooecia 9
   Diaphragms abundant in autozooecia 12

9. Mesozooecial walls constricted at the position of the diaphragms producing a beaded appearance .... *Hetrotrypa* sp
   Mesozooecial walls straight in appearance 10

10. Branches >3 mm in diameter 11
    Branches <3 mm in diameter .... *Leioclema* sp. B

11. Acanthostyles composed of broad hyaline core with no sheathing laminae .... *Leioclema*? sp.
    Acanthostyles composed of broad hyaline core surrounded by steeply dipping conical laminae .... *Leioclema* sp. A

12. Autozooecial basal diaphragms very abundant and regularly spaced throughout colony .... *Amplexopora* sp.
    Autozooecial basal diaphragms present throughout colony but more abundant in the exozone 13

13. Meandering autozooecia roughly parallel to branch axis in endozone then curving very slightly to meet zoarial surface .... *Eridotrypa simulatrix*
    Straight autozooecia roughly parallel to branch axis in endozone curve to meet zoarial surface 14

14. Thick exozonal walls with abundant diaphragms .... *Batostoma* cf. *polare*
    Otherwise .... *Batostoma clogyfranense*

15. Mesozooecia present 16
    Mesozooecia absent, exilazooecia present . *Halloporina* cf. *crenulata*

16. Mesozooecia beaded in appearence .... *Hallopora peculiaris*
    Mesozooecia straight-walled .... *Hallopora* aff. *wesenbergiania*